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AN ANALYSIS OF THE EFFECTS OF DELAY OF REINFORCEMENT AND MOMENTARY PROBABILITIES OF REINFORCEMENT ON INTERVAL SCHEDULE PERFORMANCE

by

Charles A. Lund

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1973

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Charles A. Lund

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ABSTRACT

An Analysis of the Effects of Delay of Reinforcement and Momentary Probabilities of Reinforcement on Interval Schedule Performance

by

Charles A. Lund

Utah State University, 1973

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In two experiments pigeons were exposed to VI and FI schedules and schedules approximating both VI and FI schedules. In experiment I, the probabilities of the VI and FI components in a Mixed FI VI schedule were manipulated to create schedule contingencies approximating simple VI or FI. In experiment II, the minimum and maximum inter-reinforcement intervals were manipulated to create schedule contingencies approximating simple VI or FI. The major finding of both of these experiments was that maximal control by the dimension of time occurred as FI contingencies were approximated. Control by any one temporal value in experiment I depended on its temporal separation from 100 seconds and the probability of reinforcement associated with 100 seconds. Control by any one temporal value in experiment II depended on its temporal separation from the minimum inter-reinforcement interval and 100 seconds.

The results were discussed in terms of interval schedule control as a form of stimulus control.

A third experiment was performed to examine possible relationships between the pause in FI performance and the subsequent scallop. The baseline condition was contaminated by a procedure which may have produced effects which overrode experimental manipulations.

Finally, an experiment was suggested to demonstrate behavioral contrast along a temporal dimension. The argument that interval schedule control is a form of stimulus control rested on analogy and inference. A demonstration of behavioral contrast along a temporal dimension would demonstrate more directly that time is similar to other dimensions. Hence, the same principles could be used to explain schedule control as are used to explain stimulus control.

(85 pages)

INTRODUCTION

A schedule of reinforcement can be defined as a rule which relates an organism's responding to the presentation of a reinforcer. When the rule is based on the time at which the response to be reinforced is emitted relative to some environmental event, a temporally defined schedule is in effect. One member of this class of schedules is the interval schedule which specifies that the first response after a period of time has passed is reinforced. Responses which occur prior to that time have no programmed consequence. If the temporal value of the schedule is constant, a fixed-interval (FI) schedule is in effect. If the temporal value of the schedule is an average of a number of different intervals, a variable-interval (VI) schedule is in effect.

In FI performance, rate of response is an increasing function of time from the event which initiates the contingencies provided by the schedule. Little or no responding occurs in the early portion of the interval and rate of response increases throughout the interval. In VI performance, an organism's pattern of response depends on the actual distribution of intervals whose average is the temporal value of the schedule. Catania and Reynolds (1968) have reported three different effects from three different programming methods for VI schedules. The constant probability VI schedule specifies that the conditional probability of reinforcement per unit time is constant. The performance that results is a relatively constant rate of response. The arithmetic VI schedule employs an arith-

metic progression of intervals in an irregular sequence resulting in an increasing conditional probability of reinforcement per unit time. The performance that results is an increasing rate of response in time. The geometric VI schedule employs a geometric progression of intervals in an irregular sequence resulting in a decreasing conditional probability of reinforcement per unit time. The performance that results is a decreasing rate of response in time. Thus, with three different VI programming arrangements, three distinct patterns of response can be obtained.

Dews (1970) has formalized his analysis of FI performance in terms of delay of reinforcement. Reinforcement for a response at t seconds strengthens responding which occurs at $t - \Delta t$ seconds. The greater the value of Δt, the lower the response rate at time $t - \Delta t$ since response rate is inversely related to delay of reinforcement or Δt. Catania and Reynolds (1968) have analyzed their results in terms of the effects of momentary probabilities of reinforcement. As the momentary probability of reinforcement associated with responding at time t increases, rate of response at time t increases. For VI schedules the probability of reinforcement associated with responding at time t is substantially less than one. As the probability of reinforcement at time t approaches one, reinforcement contingencies are created which approximate FI contingencies. For most VI schedules the difference between maximum and minimum intervals is substantially greater than zero. As this difference approaches zero, reinforcement contingencies are created which approximate FI contingencies. Thus, there appear to be two dimensions along which FI and VI contingencies can be approximated -

probability of reinforcement associated with a particular temporal value and the difference between the maximum and minimum interval.

In the present paper, two experiments examined properties of responding as a function of the difference between the maximum and minimum intervals and the probabilities of reinforcement associated with a particular temporal value. An attempt was made to provide a unification of Dews' account of FI performance based on delay of reinforcement and Catania and Reynolds' account of VI performance based on momentary probabilities of reinforcement.

A third experiment was performed to examine effects of response suppression in early portions of a constant probability VI schedule on subsequent patterns of responding. The purpose of the experiment was to determine if sequential interactions between time periods of no responding and responding could account for increasing rates of responding in time in FI schedules. In other words, the research attempted to examine a possible relationship between the period of no responding and positively accelerated response rates observed in FI performance.

REVIEW OF THE LITERATURE

Research and Theory of FI Performance

Dews (1962) examined the role of chained responses as possible mediating behavior in FI performance. If FI performance were due to chaining, rate of response at time t + Δt would depend on rate of response at time t. Dews alternated 50 second S^- periods with 50 second S^+ periods in FI 500" to reduce response rates during 50 second S^- portions of 500 second intervals. If increasing rates in time were due to chaining, the presentation of S^- periods and reduction of response rates in their presence would affect the overall tendency for rate of response to increase during successive S^+ periods. Dews found that when S^- periods were presented, rate of response decreased in their presence but in S^+ periods, the overall pattern of responding survived. He concluded that rate of responding at time t + Δt did not depend on rate of responding at time t and therefore, fixed-interval performance was not due to chaining.

In a series of systematic replications of the experiment described above, Dews was able to substantiate the original conclusion. Procedural variations involved the substitution of a squirrel monkey for a pigeon as a subject (Dews, 1965a), changes in schedule parameters, patterns of interruptions, and stimuli employed (Dews, 1965b), the use of long S^- periods and short S^+ periods (Dews, 1966a), and occasional omission of food presentations (Dews, 1966b).

Another possible explanation for the pattern of FI performance is the preferential reinforcement of long inter-response times (IRTs). The probability that the time requirement of the schedule will elapse during an IRT of two seconds is twice the probability that it will elapse during an IRT of one second, for example. Dews (1969) examined the hypothesis that FI performance was due to such preferential reinforcement. He recorded IRT distributions for each of the final three IRTs and found that the distribution of reinforced IRTs contained longer IRTs. He then added a fixed-ratio requirement to an FI 180" thereby changing the schedule to tandem FI 180" FRX, with the values of X varying from one to nine under different conditions. This arrangement eliminated preferential reinforcement for longer IRTs but did not change the overall pattern of response. Under another condition Dews required one second to elapse between the reinforced response and reinforcement. In this case, overall rate of response was reduced but the pattern survived. Thus, Dews was able to conclude that the overall pattern of response did not depend on preferential reinforcement of long IRTs or characteristics of responding at the moment of reinforcement.

The research program of Dews was successful in eliminating chaining, preferential reinforcement of long IRTs, and response characteristics at the moment of reinforcement as contributing factors to the development of FI performance. During the course of his extensive research program Dews has loosely stated a theory of FI performance. Recently the theory has been formalized (Dews, 1970) and employs delay of reinforcement as the central concept. When an organism is exposed to FI contingencies each response prior to the

reinforced response is separated in time from reinforcement. Since all responses are followed by reinforcement, each response is strengthened by subsequent reinforcement. However, a response early in the interval is separated from reinforcement by a longer time period than a response later in the interval. There is a differential separation in time from reinforcement for responses occurring at different points in the interval. The length of the separation in time of a response from reinforcement determines the length of the delay of reinforcement for that response. Responses reinforced with shorter delays are strengthened more than responses reinforced with longer delays since response strength is inversely related to the length of the delay of reinforcement (Ferster, 1953; Dews, 1960). Thus, responding becomes increasingly more probable as the interval elapses.

Dews' account stresses that the overall pattern of response is invariant over a wide range of parameter values. While overall rate of response varies with changes in schedule parameters, the relative distribution of an organism's responses remains constant. According to Dews the invariance in the distribution of a subject's responses can be explained in terms of the delay of reinforcement relative to the length of the interval or relative delay of reinforcement.

The major difficulty with Dews' theory is not that it fails to account for the phenomenon it purports to explain. In fact, it explains the phenomenon well. With the concept of delay of reinforcement, it is possible to account for the overall pattern of responding. In addition, the relative nature of delay of reinforcement in Dews' account permits explanation of the consistency in relative patterns

of responding under different parameter values. The major problem with Dews' theory is that it restricts itself to explaining phenomena associated with only one type of schedule. Howe does delay of reinforcement operate in VI schedules to produce their characteristic effects? Dews has not as yet addressed himself to this question.

The question of whether delay of reinforcement operates in variable-interval schedules is important if delay of reinforcement is to provide an understanding of interval schedule effects in general. All interval schedules share the characteristic of providing reinforcement for the first response after a period of time has passed. The VI schedule is composed of many different intervals while the FI schedule is restricted to one. Logically, the FI schedule is a special case of the class of interval schedules. A more general theory should be developed which would account for performances on all types of interval schedules.

Some Research and Theory of VI Performance

As discussed earlier, Catania and Reynolds (1968) have reported different effects from constant probability, arithmetic, and geometric arrangements for programming VI schedules. In the same monograph, they report three experiments which illustrate the relationship between momentary probability of reinforcement and local rate of responding.

In the first experiment, they examined the effect of adding a zero second interval to an arithmetic VI schedule on local rates of responding. The

predominant effect of the zero second interval was to increase rate of response substantially in early portions of the interval.

In the second experiment, they examined the effect of adding intervals of short durations on local rates of responding. They found that the addition of short intervals increased rate of response in early portions of the interval and that the increase in rate was closely associated with the temporal value of the interval added.

In the third experiment, they examined the effects of the temporal separation of reinforcements on patterns of responding. On a baseline of FI 240" they introduced conditions in which responding was reinforced with a conditional probability of .05 at temporal values of 30, 90, 150, and 210 seconds under various conditions of the experiment. If reinforcement failed to occur at the lesser value, the first response after 240 seconds was reinforced. When reinforcement was associated with responding at 30 seconds, rate of response increased until 30 seconds had elapsed and then decreased until approximately 90 seconds had elapsed. From 90 to 240 seconds, rate increased. Under other conditions, the pattern of response approximated performance on FI 240" as the other value associated with reinforcement approximated 240 seconds. When the conditional probability of reinforcement for responding at 30, 90, 150 and 210 seconds was changed to .50, local rates of response associated with these values increased from those obtained when the conditional probability was .05.

The main conclusion drawn from these studies was that the overall pattern of response depended on the probabilities of reinforcement associated with

particular temporal values and their proximity to other temporal values and their associated probabilities of reinforcement. In other words, the overall pattern of response depended on a summation of probabilities of reinforcement associated with the intervals making up the schedules. At each value, responding was strengthened and the amount of strengthening depended on the probability of reinforcement associated with that value and other nearby values.

Although Catania and Reynolds did not discuss their data in terms of temporal discriminations or stimulus control by time, the data do suggest a conceptual similarity between control by time and control by physical dimensions such as wavelength or intensity. In a typical stimulus control experiment, a subject's performance in the presence of a particular stimulus depends on reinforcement parameters associated with that stimulus and other stimuli along that dimension. At this point, it seems necessary to examine some of the procedures and vocabulary employed in the study of stimulus control to determine possible similarities between temporal schedule control and stimulus control.

Stimulus Control and Schedule Control

Hearst, Besley, and Farthing (1970) have recently delineated two uses of the term stimulus control. One usage refers to control by the presence vs. absence of a particular stimulus. Evidence for such control is a high probability or responding in the presence of the stimulus associated with reinforcement and a low probability of responding in the presence of the stimulus associated with non-

reinforcement. The other use of the term refers to control by the dimension along which reinforcement contingencies are associated. Evidence for dimensional control is maximal responding near the value of the stimulus associated with reinforcement and lesser responding in the presence of other values along the dimension. Typically, the actual amount of responding in the presence of other values depends on the distance along the dimension from the value associated with reinforcement. As the distance increases, the probability of response decreases. It should be noted that evidence for dimensional control involves the procedure for obtaining a generalization gradient. On the other hand, evidence for control by the presence vs. absence of a particular stimulus involves the presentation of only two stimuli and observation of responding in their presence.

The notion of dimensional control of responding is relevant to understanding how interval schedules operate to produce their characteristic effects for two reasons. First, an interval schedule of reinforcement provides a rule for the relationship between reinforcement and values along a temporal dimension. Responding at certain values along a dimension is associated with certain probabilities of reinforcement in the typical interval schedule arrangement. Second, since the rule provides for differential reinforcement with respect to a temporal dimension, that dimension should acquire control over responding if differential reinforcement has occurred. Since the interval schedule is a rule which relates reinforcement to a temporal dimension and differentially reinforces responding with respect to that dimension, the controlling variables in the situation are

reinforcement probabilities and the temporal values to which they are assigned. The performance that results can be understood in terms of dimensional control since reinforcement is defined in relation to a temporal dimension and differential responding is observed in relation to values along the dimension.

The relation between schedule control and stimulus control has been obscured for five reasons. First, the two areas in the Experimental Analysis of Behavior have been treated as separate topics. Second, the procedure for obtaining a generalization gradient, an important research tool in stimulus control, differs from the procedure of exposing an organism to a schedule of reinforcement. Third, generalization gradients obtained with respect to wavelength, intensity, and so forth include values greater and less than the original training stimulus. Fourth, time in itself presents no specific antecedent stimulus energy to an orgamism. Fifth, time cannot be controlled by an experimenter.

In textbooks dealing with the Experimental Analysis of Behavior such as Honig (1966), Millenson (1967), and Catania (1968), chapters are arranged to treat the topics of schedules of reinforcement and stimulus control separately. While it may be advantageous for an author to divide his subject matter into selected topics, such a division may produce conceptual divisions in the minds of readers.

The second reason for the failure to recognize similarities between schedule control and stimulus control follows from differences in experimental procedures. The typical procedure for obtaining a generalization gradient involves a period of training followed by extinction. During the training period reinforce-

occurs in the presence of one stimulus and non-reinforcement in the presence of another stimulus. During test conditions, reinforcement is discontinued, an organism is presented with a number of stimulus values, and responding is observed in the presence of these values. With a schedule of reinforcement however, responding is observed under steady-state conditions. Response rate is determined in relation to the time at which the rate is emitted while maintaining constant conditions of reinforcement.

Blough (1969) has developed a technique for obtaining wavelength generalization gradients under steady-state conditions. In a random series of 16 trials repeated 15 times per session, four S^+ trials were randomly interspersed in which responding was reinforced. In the other twelve trials, the S^+ stimulus was presented once but responding was not reinforced and the 11 remaining stimuli were presented. During these 12 trials, responses were recorded and generalization gradients were constructed from these data. The gradients obtained were similar to those obtained using extinction for generalization testing. In a variation of the above procedure two S^+ stimuli were employed. The shapes of the gradients obtained depended on the difference between the two S^+ stimuli. As S^+ stimuli became increasingly different, the gradients obtained developed a bimodal character.

Blough's procedure represents an alternative method of generalization testing and shares two common properties with the procedure of exposing an organism to a schedule of reinforcement. First, reinforcement contingencies with respect to S^+ remain relatively constant during testing. In Blough's

procedure, the only distinguishing feature of non-reinforced S^+ test trials from reinforced S^+ trials was the non-occurrence of reinforcement. Since reinforcement during reinforced S^+ trials could occur at any time in the trial, the subjects could not discriminate a non-reinforced S^+ test trial until the trial was completed. The second common property of Blough's procedure and schedules of reinforcement was that two S^+ stimuli were employed. An obvious extension is to three or more S^+ stimuli. In the case of VI schedules reinforcement can be associated with responding at a number of temporal values. If the conditional probability of reinforcement per unit time is constant, a constant response rate develops indicating that time exerts little control over responding. Had Blough employed a larger number of S^+ stimuli with the same reinforcement contingencies, wavelength also would have exerted little control over responding.

The third reason for the failure to recognize similarities between schedule control and stimulus control is also procedural in origin. In generalization experiments, two-sided gradients are obtained in which responding is observed in the presence of values greater and less than the reinforced value. In the case of the FI schedule, responding is observed only in the presence of temporal values less than the value specified by the schedule parameter. In the case of the VI schedule, responding is observed only in the presence of temporal values less than the longest interval making up the schedule.

Catania (1970) reported an experiment in which he obtained a two-sided temporal generalization gradient using a procedure very similar to a standard FI schedule. In his experiment, a schedule of FI 10" was in effect and the first

response after 10 seconds was reinforced with a probability of .90 in one condition and .10 in another. If reinforcement did not occur, the trial continued for 38 seconds and then the inter-trial interval occurred. Response rates were determined for values greater and less than 10 seconds. Maximum rates of response under each condition were obtained near 10 seconds and rate dropped on each side of 10 seconds as a function of the temporal difference from 10 seconds. In addition, the rate of response at 10 seconds was higher in the .90 probability of reinforcement condition. Catania suggested that it might be appropriate to consider his data as a temporal generalization gradient similar to those obtained with sense modalities such as vision. However, he added that delay of reinforcement may be responsible for performance prior to 10 seconds.

The fourth reason for the failure to recognize similarities between schedule control and stimulus control is conceptual in origin. Time in itself presents no specific stimulus energy to an organism and as Catania (1970, p. 38) pointed out, involves no obvious receptor. Other dimensions such as wavelength present specifiable stimulus energies to an organism and involve known receptors. A paradox arises in the case of time because no specifiable antecedent stimulus is suggested to control responding. However, time exists independently of a subject's performance, is measurable, and in the case of temporal schedules, is the dimension according to which reinforcement contingencies are defined. In addition, rates of response are determined in relation to their time of emission. In the case of specific physical dimensions such as wavelength, the same characteristics are present. The dimension is measurable. It is independent of the subject's

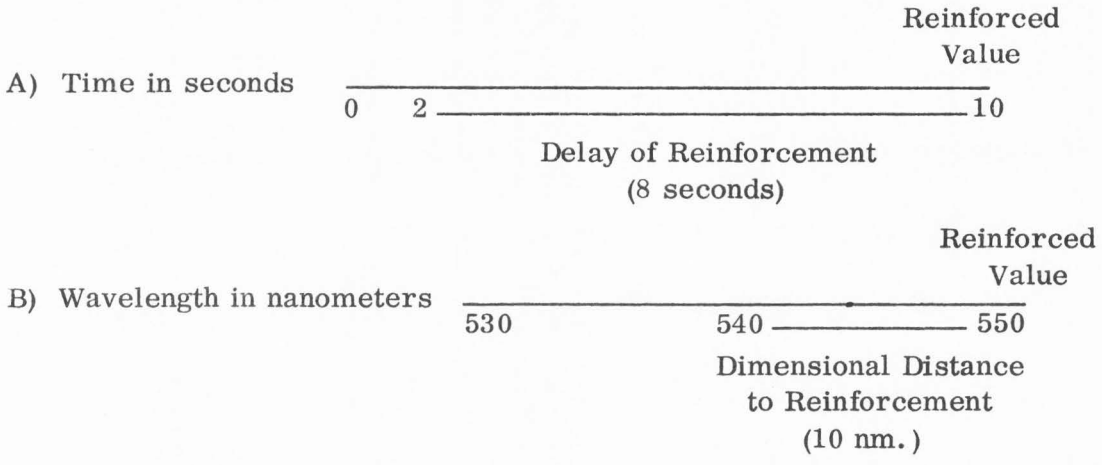
performance. Reinforcement contingencies can be defined with respect to the dimension. And, finally, responding is observed in relation to values along the dimension.

The final reason is related to the nature of the dimension of time. In the typical stimulus control experiment, a subject is presented with discrete stimulus values associated with experimentally defined reinforcement contingencies and responding is observed in their presence. If steep gradients are obtained, the dimension is said to control responding. With a temporal dimension an experimenter cannot present a value of 10 seconds, for example, as in the case of a value of 550 nanometers. However, he can manipulate reinforcement contingencies with respect to temporal values. If a subject's performance corresponds to changes in reinforcement contingencies, a shift in control has occurred. Thus, although time cannot be directly controlled to determine dimensional control, it is still possible to examine dimensional control by controlling reinforcement contingencies with respect to values along the dimension as they occur.

Delay of Reinforcement and Dimensional Distance to Reinforcement

Since delay of reinforcement has been employed to explain FI performance, it would seem worthwhile to examine other dimensions to determine if there are analogues to delay of reinforcement. Delay of reinforcement refers to the

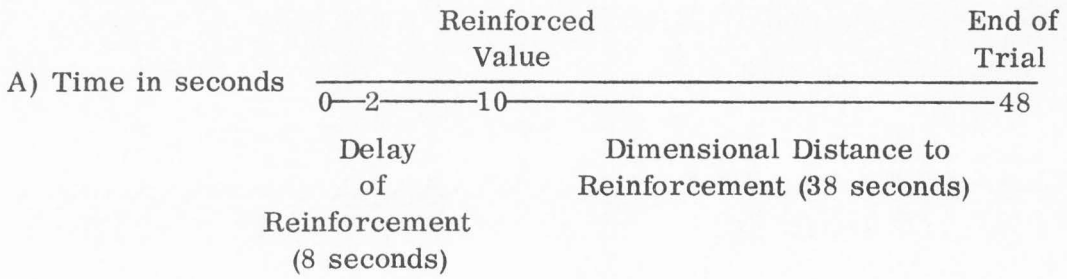
temporal separation of a response from reinforcement. Delay of reinforcement has been studied in a variety of contexts with a number of delay procedures but the research indicates that response strength is inversely related to the length of the delay. Along other dimensions such as wavelength there is a separation of a reinforced value from any other value. The actual distance of the separation can be determined by subtracting the value of the reinforced stimulus from the value of the other stimulus and can be referred to as dimensional distance to reinforcement. The following diagram employs wavelength and time as dimensions and serves to illustrate similarities between delay of reinforcement and dimensional distance to reinforcement.

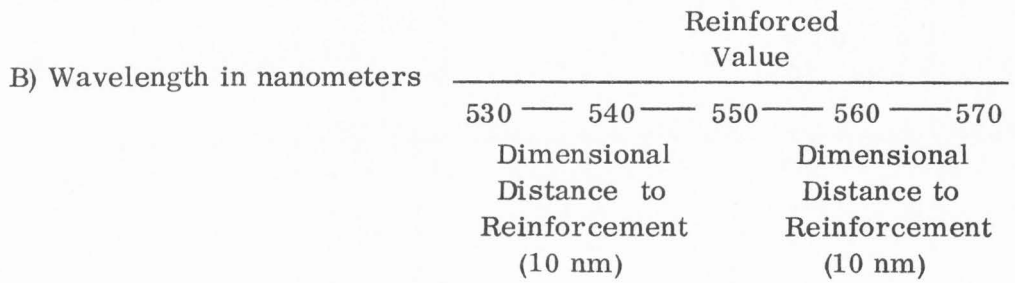


In A a time base of ten seconds is used with reinforcement for the first response after 10 seconds. A response occurring at 2 seconds is separated in time from reinforcement by 8 seconds and is less probable than a response at 9 seconds whose separation from reinforcement is 1 second. In B a portion of the wavelength dimension between 530 and 550 nm. is represented with the reinforced

value indicated at 550 nm. A response occurring in the presence of a 540 nm. stimulus is separated from reinforcement by 10 nm. A response at 540 nm. is less probable than a response at 545 nm.

If the diagram is changed to accommodate Catania's procedure for obtaining a temporal generalization gradient and the corresponding modifications are made for the dimension of wavelength, the following diagram results:





In Catania's procedure, the placement of reinforcement at 10 seconds strengthened responding at values grater than and less than 10 seconds. In a typical wavelength generalization experiment, the placement of reinforcement at 550 nm. strengthens responding at greater and lesser values. The amount of strengthening for other values depends on their dimensional distance to the reinforced value. If the dimension of time is like other dimensions, it would seem appropriate to view the effects of the reinforced value on other values in terms

of the same concept. Such a concept would account at least qualitatively for differences in responding at various dimensional points in terms of their dimensional distance to reinforcement for values less than the reinforced value as indicated in part A of the previous diagram. For values greater than 10 seconds, the dimensional distance cannot be referred to as delay of reinforcement since responding at values greater than 10 seconds is never reinforced. In part B of the diagram, there is no conflict in the use of the term dimensional distance to reinforcement for values gerater and less than 550 nm. Returning to part A of the diagram it might be possible to replace the term delay of reinforcement with the term dimensional distance to reinforcement.

Delay of reinforcement and dimensional distance to reinforcement are measured in the same manner by subtracting one value from the reinforced value. In addition, the empirical case of both parts of the diagram, response strength is inversely related to the absolute value of the dimensional distance to reinforcement. Finally, if dimensional distance to reinforcement is substituted, the ambiguous nature of the relationship between the dimension of time and other dimensions such as wavelength disappears.

Dimensional Control and Schedule Performance

In the previous sections an attempt was made to examine the relation between schedule control and stimulus control in terms of the procedures and concepts employed. The major concepts which aided in analyzing the relation-

ship have been dimensional control of responding and dimensional distance to reinforcement. The concept of dimensional control of responding suggested that time as a dimension is similar to any other dimension to which reinforcement contingencies can be assigned.

With the concept of dimensional distance to reinforcement, it was possible to view FI schedule effects and modified FI schedule effects in terms of the same independent variables as stimulus control effects. How are the concepts of dimensional control of responding and dimensional distance to reinforcement relevant to VI schedule effects?

In the first place, it is necessary to recall the procedure for demonstrating dimensional control of responding - obtaining a generalization gradient. Dimensional control is evident when responding is maximal at or near the reinforced value and decreases on either side. As the slope of the generalization gradient increases, the dimension is said to exert greater control over responding. As the slope decreases, the dimension is said to exert less control. Ray and Sidman (1970) have suggested that results of generalization testing are easy to interpret if the gradient obtained is either flat or steep. A steep gradient indicates strong control by the dimension in question while a flat gradient indicates no control by the relevant dimension. In the case of the flat gradient, Ray and Sidman suggest that alternate sources of control may be present. When an organism is exposed to a VI schedule, a more constant response rate results than in FI performance. In terms of dimensional control, time exerts little control over performance. However, a VI schedule provides reinforcement for responding

at a number of temporal values in comparison with the FI schedule which includes only one temporal value. The VI schedule shifts control to a number of temporal values. Hence, a more constant pattern of responding in time occurs. If VI performance indicates weak dimensional control by time, it is possible to identify the other sources of control - temporal values of the schedule and their associated reinforcement parameters. In addition, properties of responding at values other than reinforced values depend on the dimensional distance to the reinforced values.

STATEMENT OF THE PROBLEM

Temporally defined schedules provide a temporal rule relating reinforcement to an organism's responding. It has been argued that performance on FI and VI schedules should be understood in terms of the same concepts. The two major concepts advanced have been dimensional control of responding and dimensional distance to reinforcement. These concepts were borrowed from the literature of stimulus control, and if they are fruitful concepts in understanding interval schedule control, the following conditions must be met:

1) FI and VI performance represent extremes on a continuum of temporal control with maximal control occurring when FI schedule contingencies are approximated and minimal control when VI contingencies are approximated.
2) The amount of dimensional control should be quantifiable under varying temporal conditions of reinforcement.
3) When dimensional control is weak, other sources of control must be specified and the amount of control must be systematically related to these other sources.

In the present experiments, temporal contingencies of reinforcement were created which approximated FI and VI schedule contingencies as well as intermediate contingencies. The purpose of exposing an organism to these conditions was to examine properties of responding under varying temporal conditions of

reinforcement to evaluate the concepts of dimensional control of responding and dimensional distance to reinforcement according to the criteria described above. Two methods of creating varying degrees of FI and VI contingencies were employed. The first method employed a Mixed FI VI schedule in which FI and VI schedules were in effect in an irregular sequence and no stimulus was correlated with either schedule. The probabilities of the VI and FI schedules were systematically varied from 0.0 to 1.0 with overall reinforcement frequency held constant. As the probability of the FI component approached 1.0, temporal conditions of reinforcement approximated by the VI schedule were created. The second method involved variations in the minimum and maximum inter-reinforcement intervals with overall reinforcement frequency held constant. A VI schedule was employed with intervals ranging from 0 to 200 seconds. As the range of intervals became smaller (e.g., 70 to 130 seconds, 90 to 110 seconds) temporal conditions of reinforcement approximating FI contingencies were created.

A third experiment was performed to examine sequential interactions between periods of no responding and subsequent periods of responding in a constant probability VI schedule. If suppression of responding in early portions of a constant probability VI schedule resulted in positively accelerated reates of response, it could be argued that suppression of responding in early portions of FI schedules may also be responsible for the positively accelerated response rates.

EXPERIMENT I

Introduction

The purpose of the experiment was to examine the behavioral effects of a number of schedules which lie along a continuum of interval schedules. Fixed and variable-interval schedules represent extremes of this continuum. The probability of the variable-interval component was varied from zero to one in Mixed FI VI. Thus, at extreme values, fixed and variable-interval schedules were in effect. The effects of varying the probability of the variable-interval component were determined by examining changes in the overall distribution of responding throughout the fixed-interval schedule when it was in effect.

Method

Subjects

One subject (HJ5) was a white king pigeon and the other subject (HJ6) was a homing pigeon. Both subjects were naive males reduced to 80-85 percent of their free-feeding weights.

Apparatus

A three key pigeon chamber, 16 x 16 x 16 inches., was illuminated by a 110 volt, 7 watt houselight throughout each session. The hopper was located

4 inches above the floor and the middle key, located above the hopper, was 9 1/2 inches above the floor. Only the middle key, illuminated by a green light, was operative during an experimental session. The chamber was placed in a larger sound attenuating box equipped with a blower for ventilation and sound masking. Electromechanical equipment, located outside the experimental room, was used to control reinforcement contingencies and record data. A cumulative recorder provided a continuous record of responding.

Procedure

Key pecking was shaped and maintained by providing 3.5 seconds access to Purina pigeon chow. After each key peck, the key light was darkened for the duration of the operating time of a pulseformer, approximately 40 milliseconds. The key light was also darkened during reinforcement. Following several preliminary sessions in which schedule values were raised to 100 seconds, one subject (HJ5) was initially exposed to a Mixed FI 100" VI 100" schedule with a VI component probability of 1.0. The other subject (HJ6) was exposed to a Mixed FI 100" VI 100" schedule with a VI component probability of 0.0. When successive performances were stable, the VI component probabilities were manipulated in the sequence shown in Table 1. Thus, for both subjects the schedules were gradually transformed from VI 100" to FI 100" and from FI 100" to VI 100". An arithmetic VI schedule was used when the VI component was in effect and consisted of the following order of intervals: 0, 140, 130, 170, 60, 160, 20, 80, 50, 150, 100,

Table 1

Summary of conditions for each subject

Condition	HJ5		HJ6	
	VI Component Probability	Number of Sessions	VI Component Probability	Number of Sessions
1	1.0	23	0.0	60
2	.90	16	.10	13
3	.70	10	.30	7
4	.50	21	.50	9
5	.30	6	.70	6
6	.10	9	.90	6
7	0.0	26	1.0	18
8	.10	7	.90	15
9	.30	16	.70	8
10	.50	9	.50	6
11	.70	6	.30	7
12	.90	12	.10	6
13	1.0	18	0.0	25

180, 10, 70, 30, 190, 120, 90, 200, 40, and 110 seconds. The stability criterion employed in the 0.0 and 1.0 VI component probability conditions consisted of five consecutive sessions in which none of the overall rates of response varied from the mean by more than 10 percent. In other conditions, stability consisted of three sessions meeting this criterion following at least three sessions of initial exposure to a condition. Daily sessions were one hour long.

When the FI component was in effect, the distribution of a subject's responses was determined by recording responses in 10 second class intervals. When the VI component probability was 1.0, the distribution of a subject's responses was determined by recording responses in 10 second class intervals for the first 100 seconds.

Results

From the distribution of responses obtained when the FI component was in effect, local rates of response were calculated and divided by the average rate of response when the component was in effect. Thus, a measure of a subject's relative rate of response was obtained for each ten second class interval. When a VI component probability of 1.0 was in effect, local rates of response were calculated and divided by the overall rate of response.

For each condition relative rate of response was plotted as a function of the relative time of emission of that rate. Straight lines were fitted to the data points by the method of least-squares (Guilford, 1954). This method of analysis provides a consistent basis for evaluating changes in the pattern of

response throughout conditions of the experiment. In addition, it provides a quantitative picture of changes in pattern of response since changes in slopes and intercepts as estimated by the least-squares method reflect changes in the pattern of response. Increases in slope and decreases in the intercept reflect the overall tendency for relative response rate to increase in time.

In Figure 1, relative response rates are plotted as a function of their relative times of emission for the VI to FI sequence for subject HJ5. As the probability of the VI component decreased from 1.0 to 0.0, relative rates of response in early portions of the interval decreased while relative response rates in later portions of the interval increased.

Figure 2 shows the same data for the last six conditions of the FI to VI sequence for subject HJ5. As the probability of the VI component increased from .10 to 1.0, relative rates increased in earlier portions of the interval and decreased in later portions of the interval.

Figure 3 shows the same data over the last six conditions of the VI to FI sequence. The data are qualitatively similar to the data shown in Figure 1 for subject HJ5. As the probability of the VI component decreased from .90 to 0.0, relative response rates in early portions of the interval decreased and relative response rates in later portions of the interval increased.

Figure 4 shows the results from the FI to VI sequence. As the probability of the VI component increased, relative response rates in early portions of the interval increased and relative response rates in later portions of the interval decreased.

Figure 1: Relative rate of response as a function of relative time of emission of that rate for the VI to FI sequence for subject HJ5. The probability of the VI component is listed for each condition.

HJ 5

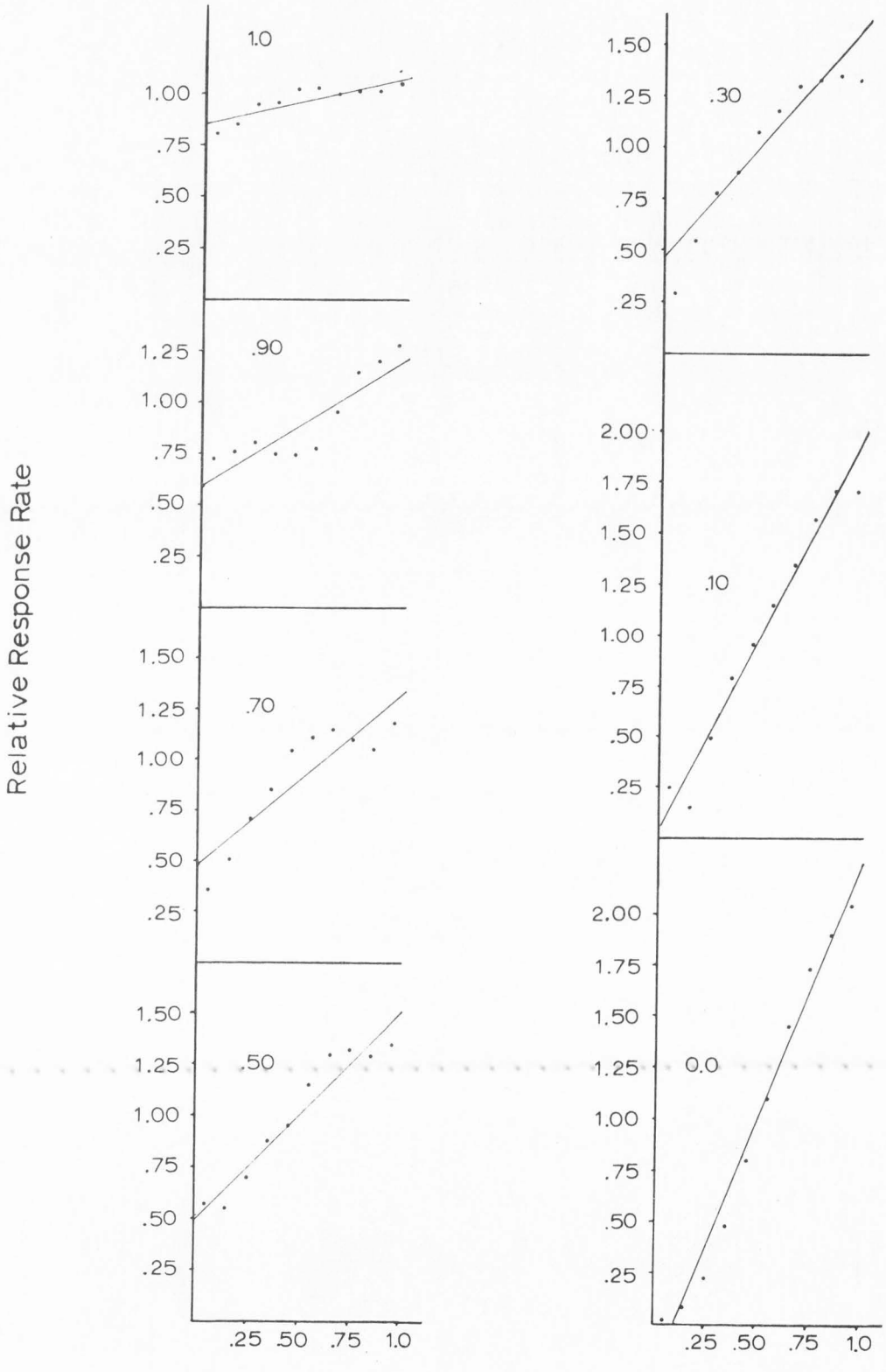

1.0
.90
.70
.50
.30
.10
0.0
Relative Response Rate
Relative Time In Interval
.25 .50 .75 1.0

Figure 2: Relative rate of response as a function of relative time of emission of that rate for the last six conditions of the FI to VI sequence for subject HJ5. The probability of the VI component is listed for each condition.

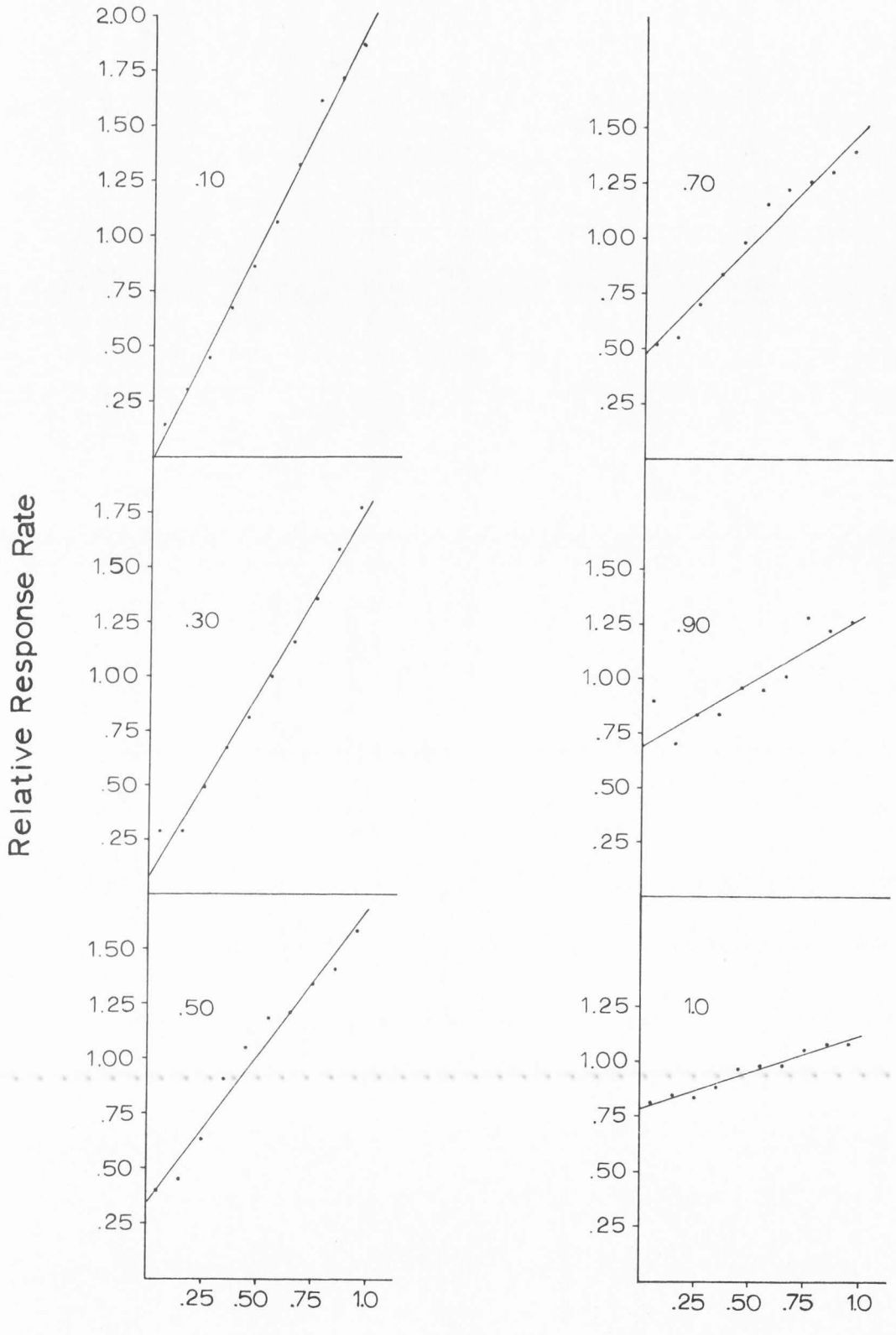

Relative Response Rate
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.10
.30
.50
.70
.90
1.0
.25 .50 .75 1.0
Relative Time In Interval

Figure 3: Relative rate of response as a function of relative time of emission of that rate for the last six conditions of the VI to FI sequence for subject HJ6. The probability of the VI component is listed for each condition.

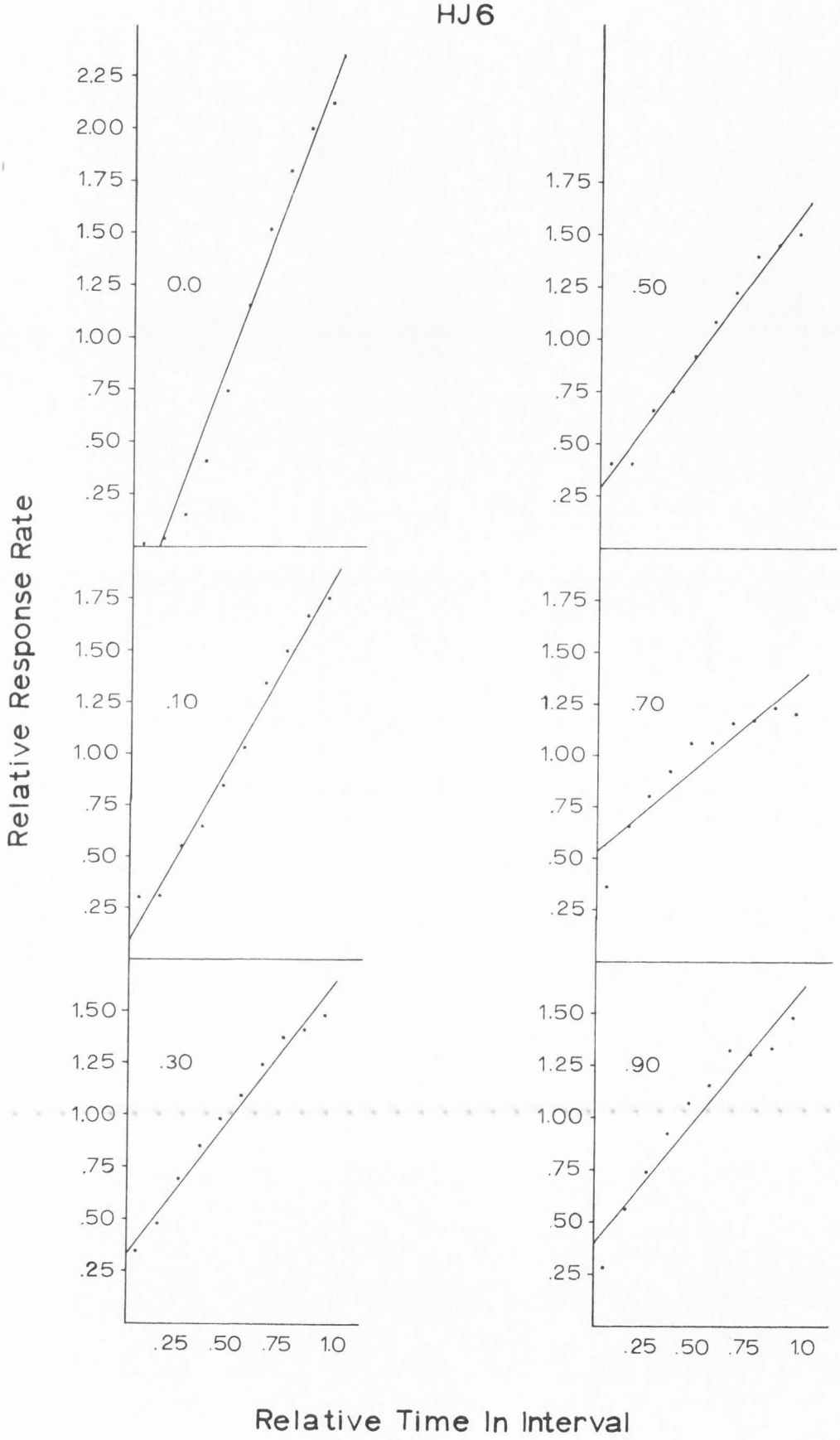

HJ6
Relative Response Rate
Relative Time In Interval
0.0
.10
.30
.50
.70
.90
2.25
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.25 .50 .75 1.0

Figure 4: Relative rate of response as a function of relative time of emission of that rate for the FI to VI sequence for subject HJ6. The probability of the VI component is listed for each condition.

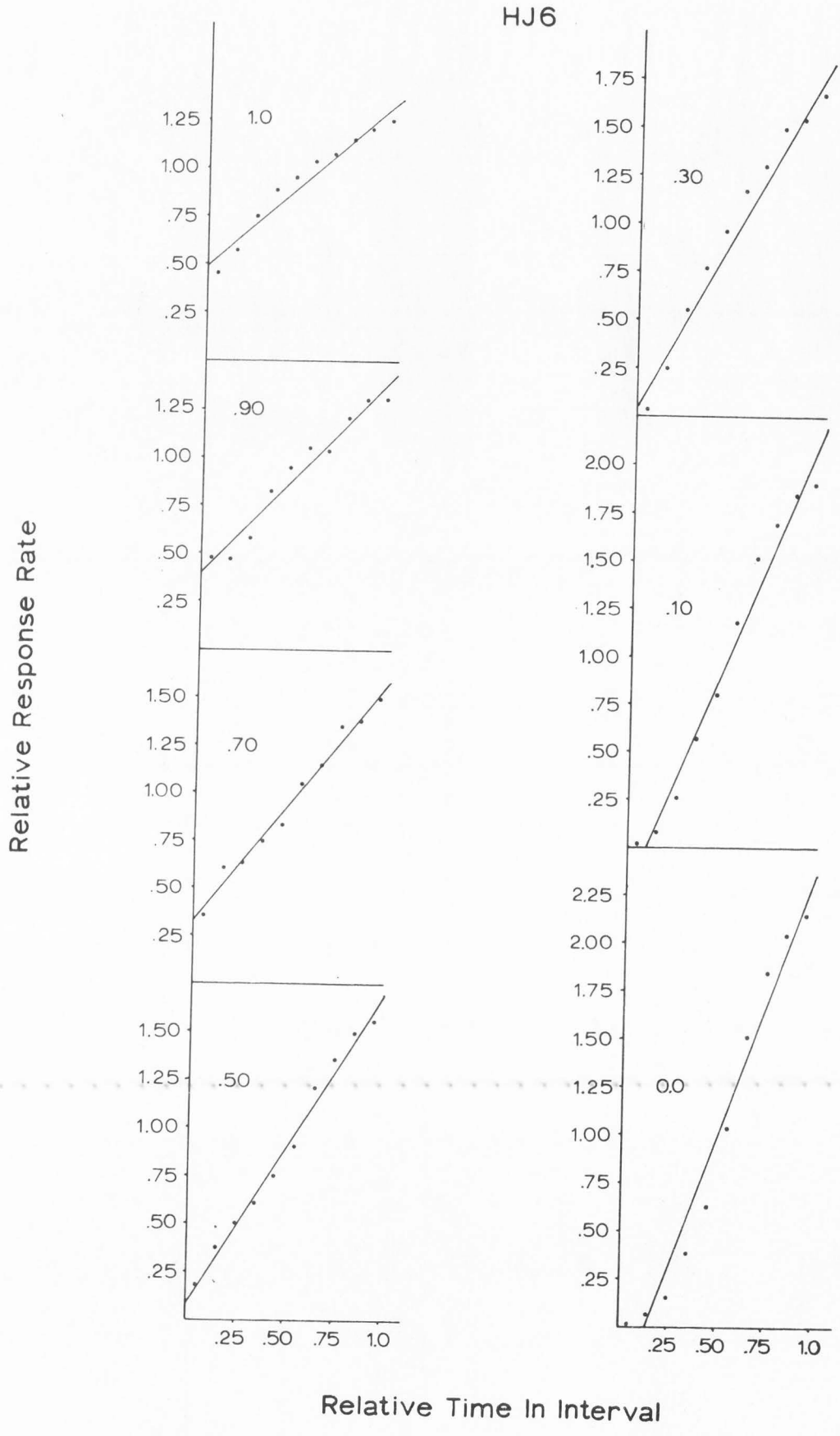

HJ6
1.0
.90
.70
.50
.30
.10
0.0
Relative Response Rate
Relative Time In Interval
.25
.50
.75
1.0

Table 2 shows the slopes and intercepts as estimated by the lines fitted to the data shown in Figure 1 through 4. For subject HJ5, the slope increased over the first seven conditions and the intercept decreased. One reversal in this trend occurred for the intercept at condition 4. Over the last 6 conditions, the slope decreased and the intercept increased. The intercepts and slopes obtained in condition 1 and 13 are not directly comparable to those obtained in other conditions since relative response rate was determined by dividing by overall rate throughout a session rather than during the first 100 seconds.

For subject HJ6, the slope decreased over the first 7 conditions and the intercept increased. The same arguments hold for the slopes and intercepts in condition 7 for subject HJ6 as for conditions 1 and 13 for subject HJ5. For conditions 8 through 13, the slope tended to increase with reversals at conditions 9 and 11.

For each subject the conditions can be divided into two sequences. In one sequence, performance was transformed from VI to FI and in the other, from FI to VI. Differences in performance were obtained for the same VI component probability depending on the sequence. For the same VI component probability, the slopes tended to be smaller and intercepts greater in the VI to FI sequence.

Table 2

Slopes, intercepts, and correlation coefficients (r) of best-fit lines for each condition of the experiment

Condition	VI Component Probability	HJ5			VI Component Probability	HJ6		
		Slope	Intercept	r		Slope	Intercept	r
1	1.0	.20	.82	.87	0.0	2.74	-.39	.98
2	.90	.62	.60	.88	.10	2.41	-.22	.99
3	.70	.86	.47	.90	.30	1.83	-.06	.99
4	.50	1.02	.50	.96	.50	1.61	.09	.99
5	.30	1.15	.43	.94	.70	1.24	.33	.99
6	.10	1.91	.06	.98	.90	1.02	.41	.98
7	0.0	2.52	-.28	.99	1.0	.81	.48	.97
8	.10	2.02	-.01	.99	.90	1.23	.40	.96
9	.30	1.73	.08	.99	.70	.85	.54	.92
10	.50	1.33	.35	.98	.50	1.36	.30	.98
11	.70	1.04	.48	.98	.30	1.30	.34	.99
12	.90	.59	.69	.98	.10	1.79	.10	.99
13	1.0	.34	.78	.97	0.0	2.71	-.36	.99

Discussion

By varying the probabilities of the VI component and FI component in a Mixed FI VI schedule, it was possible to redistribute reinforcements in time. As schedule contingencies approximated a simple VI schedule, performances were obtained which approximated VI performance. Likewise, as schedule contingencies approximated a simple FI schedule, performances were obtained which approximated FI performance. The degree to which responding was differentially reinforced with respect to time determined the degree to which differential responding with respect to time occurred. In other words, the amount of dimensional control by time was determined by the degree of differential reinforcement with respect to time. As the probability of the VI component decreased, greater control was exerted by time as evidenced by increases in slopes obtained for the best-fit lines. Control was maximal as FI contingencies were approximated and minimal as VI contingencies were approximated. The slope of the best-fit lines represents the actual amount of control exerted by the dimension of time. Therefore, the amount of control was quantifiable.

Smaller values of slopes obtained for best-fit represented weak dimensional control by time. As reinforcement became equally probable for responding at a number of points in time, each point exerted approximately the same amount of control resulting in a decrease in the amount of dimensional control. Thus, decreases in dimensional control were related to shifts to approximately equal control by a number of temporal values. The actual amount of control by

one value as represented by relative response rate depended on two factors. One was the reinforcement probability associated with responding at that value. The other was the dimensional distance to 100 seconds. Except in the VI component condition of 1.0, reinforcement for responding at 100 seconds was much more frequent than for any one value less than 100 seconds. Although the probabilities of reinforcement for responding at 10 seconds and 90 seconds were somewhat similar, relative response rate was much higher at 90 seconds due to its proximity to 100 seconds. Thus, control by any particular value depended on the distance to 100 seconds and the probability of reinforcement associated with that value and 100 seconds.

The differences found in the VI to FI sequence and FI to VI sequence are probably traceable to the subject's immediate histories. Weiner (1969) found that human FI performance was differentially affected by previous exposure to different schedules. In the present experiment, performance in a condition appeared to be differentially affected by whether a subject had been exposed more recently to a VI schedule or FI schedule. If a subject had been more recently exposed to a VI schedule, performance in the condition could be characterized by higher response rates in early portions of the interval with a tendency for rate to remain more constant. If a subject had more recent exposure to the FI schedule, performance in the same condition was characterized by lower response rates in early portions of the interval with a tendency for rates to increase more rapidly in time. The results in both sequences did remain qualitatively similar, nonetheless.

EXPERIMENT II

Introduction

An alternative method of defining a continuum of interval schedules was in terms of the amount of variability among inter-reinforcement intervals whose average was constant. When variability was zero, a fixed-interval schedule was in effect. When variability was maximum, a variable-interval schedule is in effect. Or, in other words, when the difference between the minimum and maximum inter-reinforcement interval was theoretically zero, a fixed-interval schedule was in effect. As the difference increased, the schedule was more like a variable-interval schedule than a fixed-interval schedule. In experiment two, the behavioral effects of selected schedules at various points along a continuum of interval schedules was examined. The main difference between experiments one and two was the method of defining the continuum. The behavioral effects of schedules along this continuum were determined by changes in the overall distribution of responses throughout the first 100 sedonds of responding.

Method

Subjects

Two naive male white king pigeons reduced to 80-85 percent of their free-feeding weights served as subjects.

Apparatus

The same apparatus was employed as in experiment I.

Procedure

Key light contingencies, reinforcement, and reinforcement time were the same as in experiment I. Subjects were given training at schedule values lower than in the initial condition. In the initial condition subject HJ7 was exposed to VI 100" and subject HJ8 was exposed to FI 100". The schedule employed the same sequence of intervals as in experiment I and the stability criterion was the same.

After performance stabilized, the minimum and maximum inter-reinforcement intervals were varied for each subject in the sequence listed in Table 3. Thus, the schedule for subject HJ7 was gradually transformed from VI to FI over conditions 1 through 7 and from FI to VI over conditions 7 through 13. For subject HJ8 the schedule was transformed from FI to VI over conditions 1 through 7 and from VI to FI over conditions 7 through 13. In every condition but the FI condition, 21 inter-reinforcement intervals were employed and equally spaced. In each condition, the distribution of a subject's responses was determined by recording responses in 10 second class intervals for the first 100 seconds.

Results

From the distribution of responses obtained during the first 100 seconds, local rates of response were calculated and divided by the overall rate of response.

Table 3

Summary of conditions for each subject

Condition	Difference Between Maximum and Minimum Inter-reinforcement Intervals	Number of Sessions	Difference Between Maximum and Minimum Inter-reinforcement Intervals	Number of Sessions
	HJ7		HJ8	
1	200"	20	0"	38
2	180"	6	20"	6
3	150"	6	60"	18
4	100"	25	100"	14
5	60"	7	150"	9
6	20"	6	180"	13
7	0"	20	200"	52
8	20"	17	180"	6
9	60"	14	150"	15
10	100"	13	100"	7
11	150"	6	60"	10
12	180"	6	20"	11
13	200"	15	0"	12

A measure of a subject's relative rate of response was obtained for each 10 second class interval. Relative rates of response were plotted as a function of their relative times of emission and lines fitted to these points by the method of least-squares (Guilford, 1954).

Figure 5 shows this data for the VI to FI sequence for subject HJ7. As the difference between the maximum and minimum inter-reinforcement interval decreased, relative rate of response decreased in early portions of the interval and increased in later portions of the interval. Reversals in this trend occurred in the conditions listed 180 and 20 seconds and are reflected by increases in the intercepts of the best-fit lines obtained.

Figure 6 shows this data for subject HJ7 for the last six conditions of the FI to VI sequence. In the conditions labelled 20 and 60 seconds, relative response rates in early portions of the interval decreased from those obtained in the simple FI condition. Relative response rates in later portions of the interval increased with respect to those obtained in the simple FI condition. Over the remaining conditions in which the difference between the maximum and minimum intervals increased, relative rate of responding increased in early portions of the interval and decreased in later portions of the interval. No reversals in this trend occurred.

In Figure 7 the same data are plotted for subject HJ8 for the last six conditions of the VI to FI sequence. As the difference between the maximum and minimum intervals decreased, relative rate of response decreased in early portions of the interval and increased in later portions of the interval. In the

Figure 5: Relative response rate as a function of relative time of emission of that rate for the VI to FI sequence for subject HJ7. The difference between the maximum and minimum inter-reinforcement interval is listed for each condition.

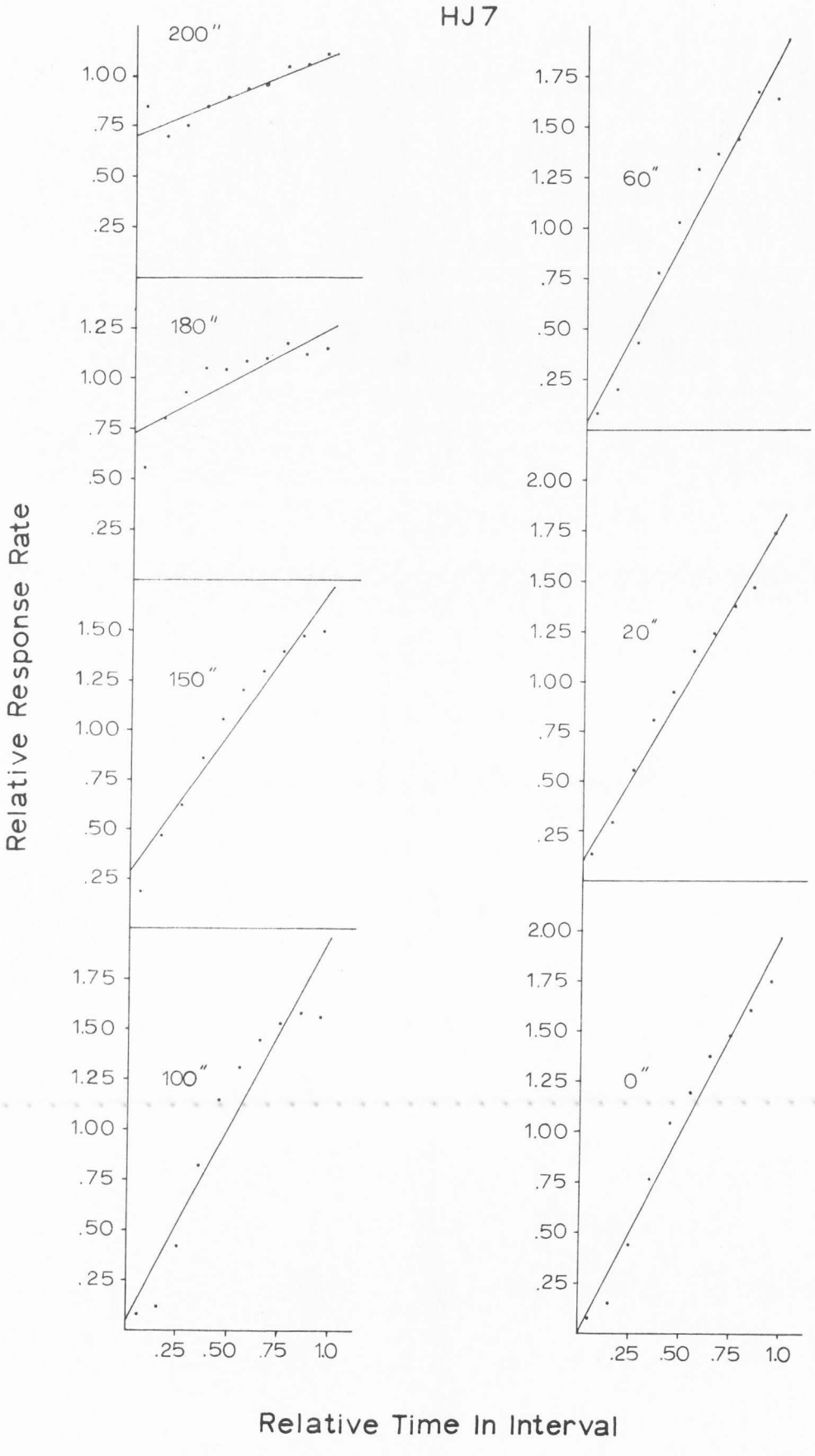

HJ7
200"
180"
150"
100"
60"
20"
0"
Relative Response Rate
Relative Time In Interval
.25
.50
.75
1.0
1.25
1.50
1.75
2.00

Figure 6: Relative response rate as a function of relative time of emission of that rate for the last six conditions of the FI to VI sequence for subject HJ7. The difference between the maximum and minimum inter-reinforcement interval is listed for each condition.

HJ 7

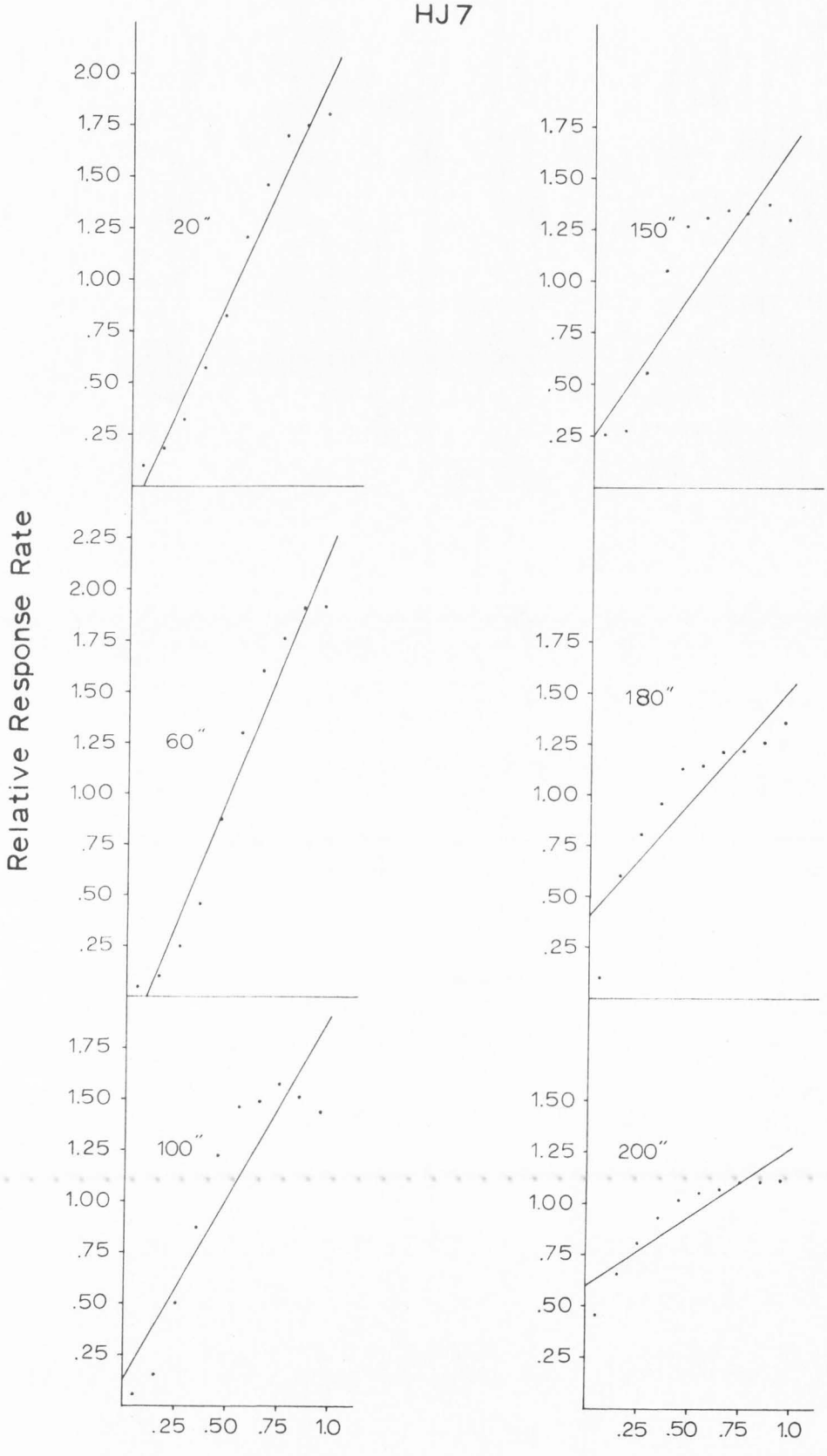
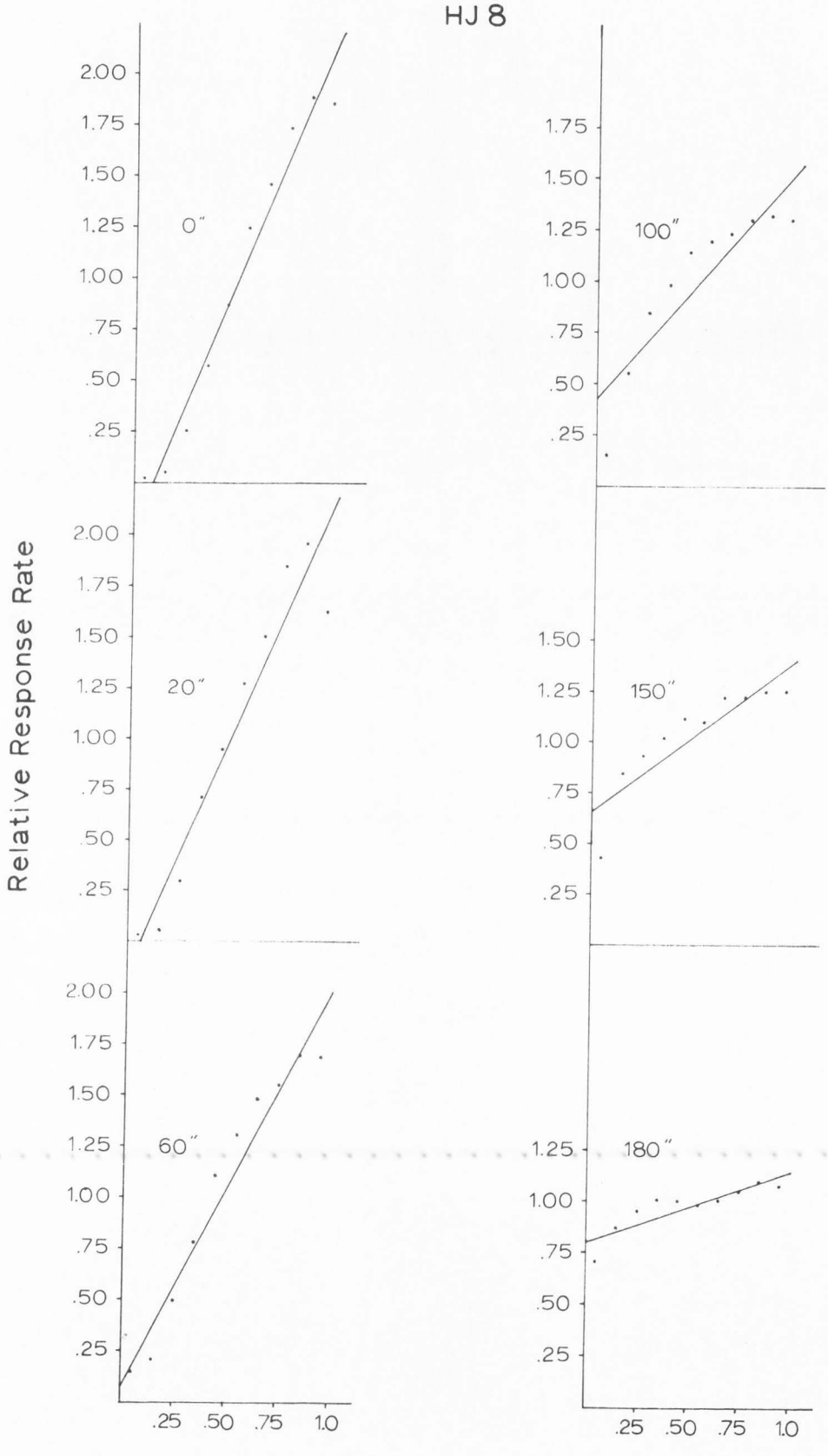

Relative Response Rate
20″
150″
60″
180″
100″
200″
.25 .50 .75 1.0
Relative Time In Interval

Figure 7: Relative response rate as a function of relative time of emission of that rate for the last six conditions of the VI to FI sequence for subject HJ8. The difference between the maximum and minimum inter-reinforcement interval is listed for each condition.


HJ 8
Relative Response Rate
Relative Time In Interval
0"
20"
60"
100"
150"
180"
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.25
.50
.75
1.0

condition listed 180 seconds, however, relative response rate increased in early portions of the interval and decreased in later portions of the interval in comparison with the simple VI condition.

Figure 8 shows this data for the FI to VI sequence. For the conditions listed 0, 20, and 60 seconds, response rates decreased in early portions of the interval and increased in later portions of the interval. Over the remaining conditions, relative rate of response increased in early portions of the interval and decreased in later portions of the interval.

Table 4 summarizes the slopes and intercepts obtained for all conditions of the experiment. For subject HJ7, the slope increased over the first seven conditions with one reversal at condition 6. Intercepts decreased with reversals in conditions 2 and 6. Over conditions 8 through 13, the slope increased in conditions 8 and 9 and then decreased with no reversals. Intercepts decreased in conditions 8 and 9 and then increased in conditions 10 through 13.

For subject HJ8, slope increased over the first three conditions and decreased over conditions 4 through 7. Intercepts decreased over the first three conditions and increased over conditions 4 through 7. Over conditions 8 through 13, slope increased and intercepts decreased. In condition 8, the slope was lower and the intercept higher than in condition 7.

Some sequence effects were obtained when performance was transformed from VI to FI or FI to VI. The major effect occurred in the FI to VI sequence. Following exposure to the FI 100" schedule (or 0" difference between maximum and minimum inter-reinforcement interval) slopes increased and intercepts

Figure 8: Relative response rate as a function of relative time of emission of that rate for the FI to VI sequence for subject HJ8. The difference between the maximum and minimum inter-reinforcement interval is listed for each condition.

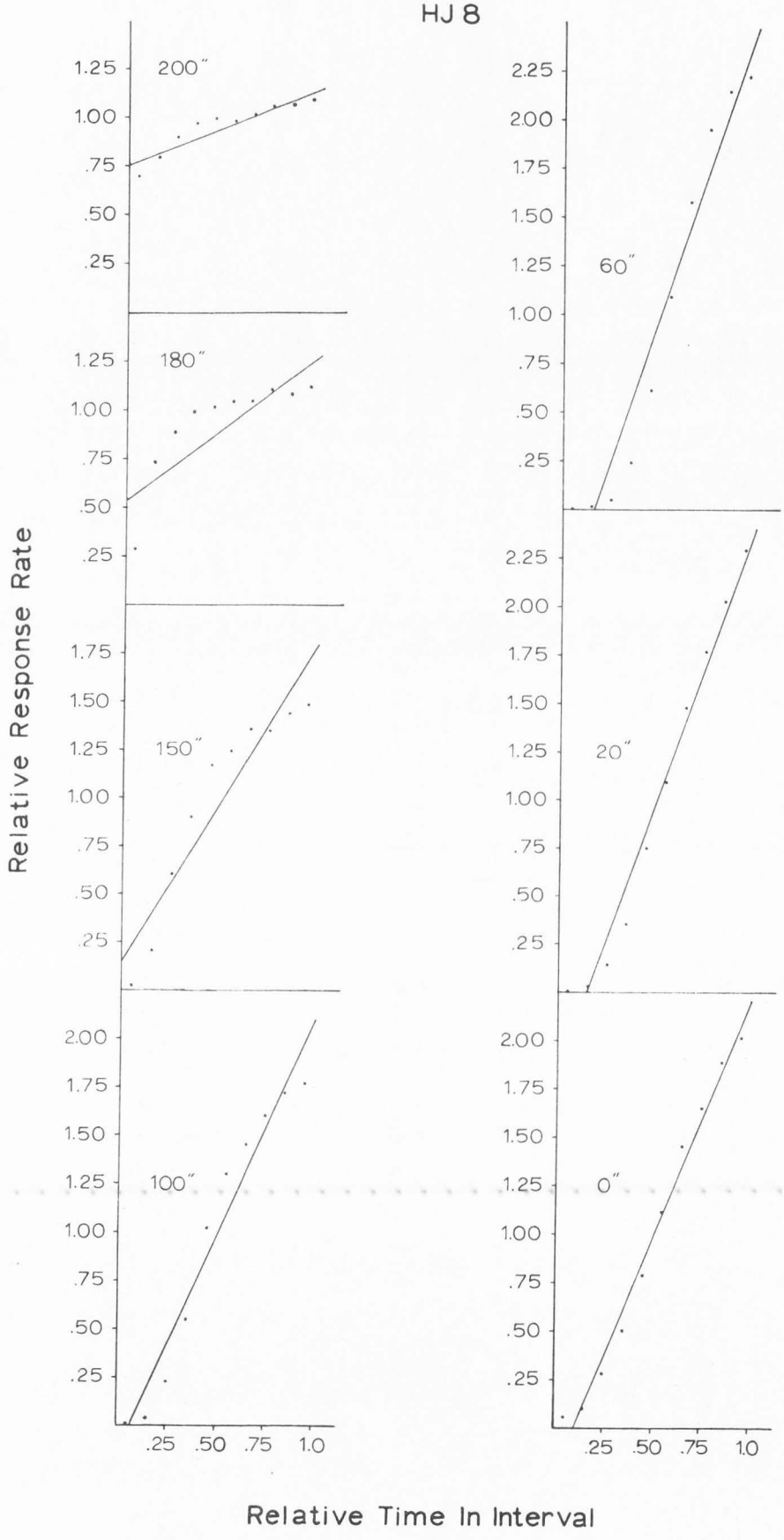

200″
180″
150″
100″
60″
20″
0″
Relative Response Rate
Relative Time In Interval
.25
.50
.75
1.0

Table 4

Slopes, intercepts, and correlation coefficients (r) of best-fit lines for each condition of the experiment

Condition	Difference Between Maximum and Minimum Inter-reinforcement Interval	HJ7			Difference Between Maximum and Minimum Inter-reinforcement Interval	HJ8		
		Slope	Intercept	r		Slope	Intercept	r
1	200"	.41	.70	.93	0"	2.44	-.23	.99
2	180"	.53	.73	.86	20"	2.81	-.41	.99
3	150"	1.44	.28	.97	60"	2.95	-.48	.97
4	100"	1.89	.06	.95	100"	2.27	-.16	.98
5	60"	1.91	.04	.98	150"	1.63	.16	.93
6	20"	1.72	.11	.99	180"	.69	.59	.81
7	0"	1.96	.01	.99	200"	.39	.76	.93
8	20"	2.19	-.11	.99	180"	.33	.81	.87
9	60"	2.48	-.22	.98	150"	.74	.67	.88
10	100"	1.77	.14	.91	100"	1.14	.43	.85
11	150"	1.46	.25	.87	60"	1.93	.08	.97
12	180"	1.14	.41	.90	20"	2.31	-.13	.96
13	200"	.67	.60	.91	0"	2.40	-.21	.99

decreased for the next two conditions for both subjects. This effect did not occur in the VI to FI condition as slopes were greater and intercepts smaller in the FI condition than in the two prior conditions. In addition, in the VI to FI sequence, slopes tended to be smaller and intercepts greater for the same difference between the maximum and minimum inter-reinforcement interval.

Discussion

As the difference between the minimum and maximum inter-reinforcement interval approached zero seconds and a schedule approximating FI was created, performance approximating FI performance developed. As the difference between the minimum and maximum inter-reinforcement interval approached 200 seconds, a schedule approximating the VI was created. The performance that developed approximated VI performance. In terms of dimensional control by time, the degree to which responding was differentially reinforced with respect to time determined the amount of dimensional control by time. As in experiment 1, the slopes of the best-fit lines provide a quantitative measure of the amount of dimensional control.

Decreases in slopes indicating weaker dimensional control were systematically related to shifts in the temporal distribution of reinforcements. As reinforcement became more "spread out", control was shifted to a number of temporal values. The amount of control by any one temporal value depended on its distance from the minimum inter-reinforcement interval and its distance to 100

seconds. A value of 80 seconds, for example, exerted greater control when the minimum inter-reinforcement interval was 50 seconds as opposed to zero seconds. In addition, a value of 80 seconds exerted greater control than a value of 50 seconds regardless of the minimum inter-reinforcement interval because of its proximity to 100 seconds.

As in experiment I, effects different from those obtained in the VI to FI sequence were obtained in the FI to VI sequence. The major discrepancy between the two sequences was the increase in dimensional control over the first two conditions of the FI to VI sequence. That is, control increased when the difference between the maximum and minimum inter-reinforcement interval increased from 0 to 20 to 60 seconds. In the VI to FI sequence, control increased when the difference decreased from 60 to 20 to 0 seconds. For subject HJ7, the FI to VI sequence occurred after the VI to FI sequence. Thus, responding at lower temporal values was associated with reinforcement in the more remote history of the subject. The continued non-reinforcement for responding at these values may have had the effect of further reducing their associated response rates. For subject HJ8 the FI to VI sequence occurred prior to the VI to FI sequence. Responding at lower temporal values had never been reinforced except in initial shaping sessions. Thus, responding at these values may have been further reduced from continued non-reinforcement.

EXPERIMENT III

Introduction

The purpose of the experiment was to determine the effects of reversing the functional properties of early portions of a variable-interval schedule. In variable-interval schedules, the initiating event is occasionally followed shortly in time by a reinforced response. In fixed-interval schedules, it is never followed by a reinforced response. Pauses develop in the FI performance but not in the early portion of VI performance. The termination of the initial pause in FI performance is often followed by positively accelerated response rates. While these features of FI performance occur successively in time, the possible contribution of the initial pause to the development of positively accelerated response rates has yet to be determined. The present experiment was designed to determine if positively accelerated response rates are related to the initial pause.

Method

Subjects

Two naive male white king pigeons reduced to 80-85 percent of their free-feeding weights served as subjects.

Apparatus

A three key pigeon chamber, 16 1/2 in. high by 16 1/2 in. wide by 17 in. long, was illuminated by a 24 volt 7 1/2 watt houselight. The hopper was located 3 1/2 in. above the floor and the middle key, located above the hopper, was 9 in. above the floor. A vertical array of five red 24 volt, 7 1/2 watt lamps was located 6 1/2 in. to the right of the center key. The bottom lamp was 4 1/2 in. above the floor and each lamp was separated from adjacent lamps by 2 in. The chamber was placed in a larger sound attenuating box equipped with a blower for ventilation and sound masking. Electromechanical equipment located outside the experimental room, was used to control reinforcement contingencies and record data. A cumulative recorder provided a continuous record of responding. A Lehigh Valley Multiplexer was used to record subjects' responding and inter-reinforcement intervals provided by the schedule.

Procedure

Key pecking was shaped and maintained by providing 3.5 seconds access to Purina Pigeon Chow. Following each response the key light was darkened for approximately 40 milliseconds. After reinforcement, the chamber was darkened for 50 seconds. After preliminary exposure to schedule values lower than VI 100", subject HJ1 was exposed to a Mult VI 100" TO 50" schedule for 61 sessions and subject HJ2 for 64 sessions. On the basis of preliminary research conducted by this investigator, a stimulus was introduced during the first 10 seconds which changed

independently of responding after 10 seconds had passed. The stimulus consisted of the illumination of the vertical array of lights. After 10 seconds passed the lights went off and the color of the center key changed from white to red. The schedule itself was not changed, however. This condition will be referred to as condition A.

In conditions B and C, a response in the initial portion of the VI 100" component when the key light was white and the array of lights were illuminated produced a 50 second time-out. The purpose of this procedure was to suppress responding in the first 10 seconds of the interval. The stimuli in conditions A, B, and C are described in Table 5. In condition C, the key light was white, the vertical array of lights was illuminated for 20 seconds rather than 10 seconds, and a response in the first 20 seconds produced a 50 second time-out. This procedure was designed to suppress responding in the first 20 seconds. Condition D was the same as condition A.

The VI 100" component was programmed by an electronic timer which produced impulses at 5 second intervals through a probability gate set at .05. One in every 20 impulses on the average set up reinforcement. In conditions B and C, if reinforcement was set up prior to the stimulus change at 10 or 20 seconds, it was produced by the first response after the stimulus change.

Response distributions and inter-reinforcement intervals were recorded by a Lehigh Valley Multiplexer which produced sessions records on paper tape. These tapes were subsequently analyzed by a PDP - 8L computer. Data from

Table 5

Summary of stimuli employed in different conditions of the experiment

Conditions A & B	Key light white, vertical array illuminated	Key light red
	0 — 10	
Condition C	Key light white, vertical array illuminated	Key light red
	0 — 20	

Time in seconds

the last five sessions of each condition were analyzed. Table 6 lists the number of sessions of exposure to each condition. Daily sessions were on hour long.

Results

Relative rates of responding were determined in ten second class intervals for the first 200 seconds of responding. Local rates of response were first calculated and then divided by the average rate of response in the first 200 seconds.

In Figure 9, relative rate of response is plotted as a function of time of emission of that rate. The performance of subject HJ1 is denoted by circles and the performance of HJ2 by squares. In condition A, maximum response rates occurred in the first 50 seconds and decreased in time. No changes occurred in condition B. In condition C maximum rates of response occurred in the first 50 seconds and then decreased in the next 100 second period. In the final 50 second period, there was a tendency for rates to increase but not to the level in the first 50 seconds. In condition D, maximum response rates occurred in the first 50 seconds but did not decline as rapidly in time as in other conditions of the experiment.

Discussion

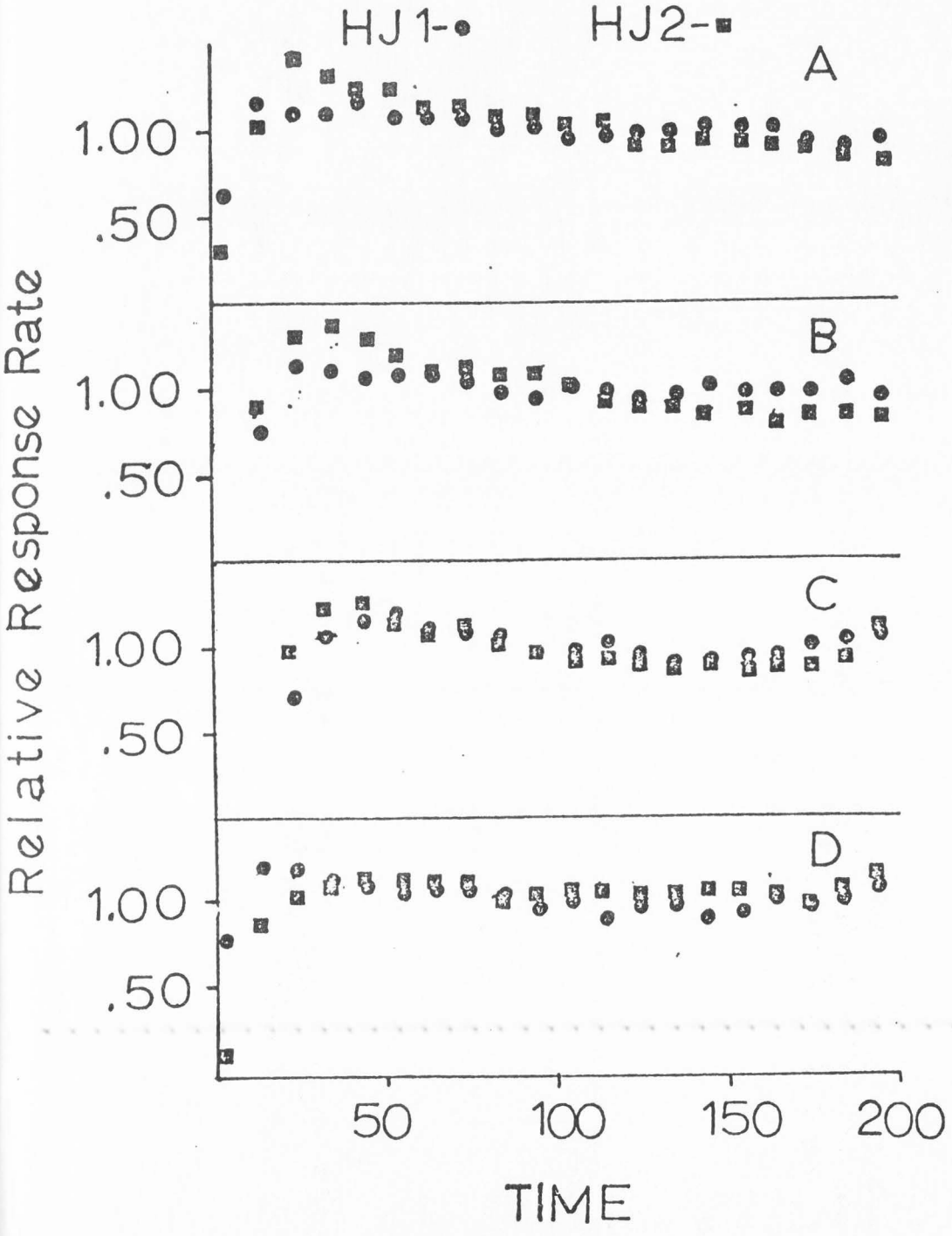
If suppression of responding in the first 10 or 20 seconds of performance produced increasing rates of response in time, it could be argued by analogy that the pause in the initial portion of FI performance was responsible for the positively

Table 6

Number of sessions of exposure to each condition

Condition	HJ1	HJ2
A	50	51
B	18	17
C	14	15
D	30	31

Figure 9: Relative response rate as a function of time of emission of that rate for various conditions of the experiment. Data for subject HJ1 is denoted by circles and data for subject HJ2 is denoted by squares.


HJ1-•
HJ2-■
A
B
C
D
1.00
.50
Relative Response Rate
50
100
150
200
TIME

accelerated rates of responding. In the present experiment, suppression of responding in the first 10 and 20 seconds failed to produce increasing rates in time. In fact, suppression of responding failed to produce any drastic change in the pattern of response. There are two arguments which can be made to account for the present data.

The first is that suppression of responding in early portions of performance is not related to the production of increasing rates of responding in time. This argument is appealing since it eliminates the possibility that the pause in FI performance is related to the subsequent "scallop". However, the other remaining possibility suggests that this account may be untenable.

The second argument is based on the phenomenon of transient contrast. Nevin and Shettleworth (1966) reported that performance in the VI component of a Mult VI EXT schedule is characterized by higher response rates in early portions of the VI component than in later portions. They referred to this phenomenon as transient contrast. In the present experiment, a Mult VI TO schedule was employed. Response rates tended to be higher in the initial portion of the VI component than in subsequent portions. It appears that this pattern of responding represented transient contrast although the TO component was not removed to determine if the pattern of response representing transient contrast would disappear. Nevertheless, the experimental procedure was contaminated by the use of a TO component which could produce transient contrast in the VI component. If the pattern of response in the VI component was due to

the effects of the TO component, the TO component effects may have overridden the effects of the experimental manipulations.

GENERAL DISCUSSION

Evaluation of the Concepts of Dimensional Control and Dimensional Distance to Reinforcement

In an earlier section of this paper, three conditions were listed for evaluating the concepts of dimensional control of responding and dimensional distance to reinforcement. The first was that dimensional control should be maximal as FI contingencies are approximated and minimal as VI contingencies are approximated. The second was that the amount of dimensional control should be quantifiable. And, finally, when time exerts little control over responding, other sources of control must be identified and the amount of control should be systematically related to these sources.

The data of experiments I and II indicate that the first condition was met. Two methods of defining the continuum between VI schedules and FI schedules were employed. In each case, performance approximated VI or FI to the degree VI or FI schedule contingencies were approximated. Minimal control occurred as VI schedule contingencies were approximated.

The slope of the lines fitted to the data points provided a quantitative measure of the amount of dimensional control. Although a more complicated non-linear model may have provided a better fit to the data points under some conditions of the experiment, the linear model generally produced a close fit to the points. Since the slopes obtained provided a measure of the amount of

dimensional control, the second condition was met.

The final condition also appears to have been met. When control was weak, it was possible to specify alternate sources of control. In experiment I, as the probability of the FI component decreased, the probability of reinforcement associated with values less than 100 seconds increased. In experiment II, as the difference between the maximum and minimum inter-reinforcement intervals increased, reinforcement became associated with a wider range of temporal values. The major effect of these manipulations was to reduce the amount of differential reinforcement with respect to time. As reinforcement was shifted to a wider range of values, shifts in control occurred to a wider range of values. It might not be appropriate to speak of the changes that occurred as indicating weaker dimensional control since the sources of control identified were other temporal values. However, the amount of dimensional control was related to the amount of control by each value. As the differential amount of control by different values decreased, dimensional control decreased. In other words, shifts in the temporal distribution of reinforcements to a number of values shifted control to these values and reduced the overall amount of dimensional control.

In experiment I, it was found that the amount of control by any one value depended on its associated probability of reinforcement and the distance of the value to 100 seconds. In experiment II the control by any one value depended on the distance to the minimum inter-reinforcement interval and the distance of the value to 100 seconds. In each case, as the distance to 100 seconds decreased, the amount of control increased. In experiment I, as the probability of reinforce-

ment associated with a value increased, the control by that value increased. In experiment II, as the temporal separation of a lower value from the minimum inter-reinforcement interval increased, the amount of control by that value decreased.

Two studies in stimulus control bear on these results. In the first study, Hearst, Koresko, and Poppen (1964) studied slopes of generalization gradients of line tilt as a function of the schedule associated with CS^+. They found that steeper gradients were obtained when a shorter VI schedule was associated with CS^+. A shorter VI schedule provided more frequent reinforcement in the presence of the CS^+. In Experiment I of this study, increases in the probability of the FI component increased the frequency of reinforcement associated with 100 seconds. As the frequency of reinforcement increased, greater dimensional control was observed.

In another study, Pierrel, Sherman, Blue, and Hegge (1970) studied the effects of $S^+ - S^-$ differences on the acquisition of an auditory intensity discrimination. They found that as the $S^+ - S^-$ difference increased, the discrimination was acquired more rapidly. In addition, the discrimination index was larger following acquisition for greater $S^+ - S^-$ differences. In experiment II, the amount of dimensional control increased as the time to the minimum inter-reinforcement interval increased. If 0 seconds is viewed as S^- and the minimum inter-reinforcement intervals S^+, these results are compatible. The amount of dimensional control in this study increased as a function of increases in $S^+ - S^-$ differences.

Comments on Experiment III

Experiment III was designed to produce positively accelerated response rates in constant probability VI performance. It was based on the notion that suppression of responding in early time periods may produce positively accelerated response rates. FI performance has been conceptualized as discriminated extinction followed by VI reinforcement (Schneider, 1969). If this were the case, interactions between the two components might be responsible for increasing rates of responding in time. However, there are two effects of an extinction component on VI performance. One has been referred to as sustained behavioral contrast and the other as transient contrast. Sustained behavioral contrast is an increase in the overall response rate in the VI component when alternated with an extinction component (Reynolds, 1961). Transient contrast occurs when the rate of response in the VI component decreases as a function of time in the component when the VI component is alternated with an extinction component (Nevin and Shettleworth, 1966). Schneider (1969) has suggested that the higher rates in the terminal portion of FI performance reflect sustained behavioral contrast produced by the period of discriminated extinction. Although this view may be correct, the period of discriminated extinction should also produce transient contrast. According to Schneider's two-state analysis, rate of response is constant in the terminal portion of the interval. Other analyses have shown that rate of response is increasing in time in later portions of the interval (Dews, 1971 and the present data). Both patterns of responding are inconsistent

with the patterns reflecting transient contrast. From Schneider's conceptualization, the prediction that transient contrast would occur following the period of discriminated extinction is unsuccessful. Although the conceptualization is intuitively appealing, it unsuccessfully predicts transient contrast.

Implications for Further Research

In this paper a case was made for viewing interval schedule control in terms of stimulus control. The data obtained have been shown to be consistent with data obtained in stimulus control experiments involving wavelength, line-tilt, auditory intensity, and other dimensions. Although there appears to be a number of similarities in relationships obtained with respect to time and specific stimulus dimensions, the argument that interval schedule control is a form of stimulus control rests on analogy and inference. Direct tests of this hypothesis are necessary. Possible tests of this hypothesis would involve attempts to demonstrate the operation of the phenomenon of behavioral contrast in interval schedule control. Since the phenomenon of behavioral contrast is well substantiated in stimulus control experiments, it should also occur in interval schedule control if interval schedule control is a form of stimulus control. An experiment should be performed to demonstrate behavioral contrast along a temporal dimension.

The following procedure would be designed to demonstrate behavioral contrast. Expose subjects to a modified Mixed FI 20" FI 60" schedule. At 20 seconds, reinforcement would be programmed for the first response through a

probability gate set at .3. At 60 seconds reinforcement would be programmed in the same manner. If reinforcement failed to occur at either value a brief black-out would be presented at 80 seconds. If reinforcement occurred, it would be followed by a black-out of the same duration. This procedure should produce approximately equal rates of responding at 20 seconds and 60 seconds since the probabilities of reinforcement given the opportunity to respond are equal. The data of interest would be the absolute rates of responding at 20 and 60 seconds. From this baseline condition, reinforcement would be eliminated for the 20 second value while programming reinforcement for the 60 second value in the same manner. Thus, the reinforcement probability given the opportunity to respond at 60 seconds would be the same as in the previous condition. If the absolute rate of response at 60 seconds increased, behavioral contrast along a temporal dimension would be demonstrated. Baseline conditions could be recovered followed by eliminating reinforcement for the 60 second value. An increase in the absolute rate of responding at 20 seconds would constitute another demonstration of contrast. The data on contrast in other dimensions suggests that reducing the reinforcement frequency in the presence of one stimulus will produce an increase in the rate of responding in the presence of another stimulus even though the schedule associated with the stimulus is not changed. If interval schedule control is a form of stimulus control, eliminating reinforcement for one value should produce an increase in the rate of responding for another value even though reinforcement contingencies with respect to that value are unchanged.

If it is possible to demonstrate behavioral contrast with this procedure, a great deal of credibility would be added to the notion that interval schedule control is a form of stimulus control. The major advantage of this conceptualization would be the unification of two previously separate areas, a reduction in the number of behavioral principles, and an increase in the generality of principles of stimulus control.

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